

CHALLENGES FOR MARINE CIVIL INFRASTRUCTURE IN THE U.S. ARCTIC

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INTRODUCTION

■ Diminishing
Arctic Sea-ice...



- Opportunities for:
- Shipping (see AMSA)
 - O&G Exploration/
Development
 - Access to Mineral
Resources
 - Tourism

INTRODUCTION

- Increased Human Activities in the U.S. Arctic
- ⇒
- Requires Capacity for/to:
 - Security
 - Search and Rescue (SAR)
 - Oil Spill Response
 - Assert Sovereignty

INTRODUCTION

- Impact of diminishing sea-ice: expect escalation of maritime operations in the U.S. Arctic
 - Increased human activity due to new opportunities
 - Enhancement in Governmental capacity to cope
- “Operating in the Arctic: Supporting U.S. Coast Guard Challenges through Research”, September 21 – 23, 2010 Sponsored by Dept. of Homeland Security, University of Alaska, Fairbanks.
- “AK Deep Draft Arctic Ports Charette”, May 16-17, 2011, Anchorage, AK

INTRODUCTION

- If we are to “operate”, where will we operate from?....
 - Maritime operations require shore-side support civil infrastructure
 - Safe harbor/ port facilities
 - Fuel
 - Food
 - Waste Handling/ Disposal
 - May require specialized support infrastructure
 - E.g., Oil-spill response

INTRODUCTION

- Is there sufficient shore-side infrastructure to support an escalation in arctic maritime operations?

INTRODUCTION

- The remainder of this presentation will consider the following questions:
 - How are some maritime operations presently supported?
 - What is the status of existing shore-side support facilities? (What assets exist?)
 - What are the engineering challenges of building new marine civil infrastructure?

INTRODUCTION

■ Clarification

- What is meant by **Marine Civil Infrastructure**:
 - Civil *Engineering* infrastructure that would support maritime operations
 - E.g.:
 - Safe Harbor/ Ports
 - Fuel/ Re-supply facilities
 - Offshore moorings
 - Aircraft runways

INTRODUCTION

■ Clarification

- What is meant by an **operation**:
 - Enterprising human activity
 - E.g.:
 - Military operation
 - O&G exploration and production activities
 - Commercial tourism activities

How are maritime operations presently supported?

- **USCG Arctic Maritime Domain Awareness Flights**
 - Originate in Kodiak
 - ~800 miles until C-130 is in the Arctic Maritime Domain



How are maritime operations presently supported?

■ Cruises to the Arctic

- Often originate in Dutch Harbor
- Sail through Bering Strait
- Time on site limited by fuel/ food
- Limited opportunities for resupply
- “AK Deep Draft Arctic Ports Charette”, May 16-17, 2011, Anchorage, AK



How are maritime operations presently supported?

■ O&G Interests

- A flotilla of vessels during “ice-free” season
- Self-sustaining

■ Tourism

- Sail into U.S. Arctic during “ice-free” season
- Also, self-sustaining

■ Mining Interests

- Lack of infrastructure has precluded production of vast mineral deposits
- Cannot export product
- **Exception:** Red Dog Mine



How are maritime operations presently supported?

■ Aircraft Facilities

- Extensive network of aircraft runways
- Most owned/ maintained by Alaska Department of Transportation and Public Facilities (AKDOT&PF)
- Larger aircraft (e.g., 737)
 - Barrow
 - Kotzebue
 - Nome
- More information at:
<http://dot.alaska.gov>



How are maritime operations presently supported?

- Typically, base of operations is far removed from theater of operations
- Generally, operation must be self-sustaining
- Larger aircraft can land in Barrow, Kotzebue or Nome



**What is the status of existing
shore-side support infrastructure?**
(What is available?)

■ **“Ports”**

- Marine Exchange of Alaska
(www.mxak.org)
- Western Alaska
- North Slope



Marine Exchange of Alaska
www.mxak.org

What is the status of existing shore-side support infrastructure? (What is available?)

■ “Ports” – Western Alaska

- Nome
- Kotzebue
- Bethel
- Point Hope
- Unalakleet



What is the status of existing shore-side support infrastructure? (What is available?)

■ Port of Nome

- South Dock
 - Bulk Cargo Dock
 - Length: 200'
 - Draft: 22.5'
- Westgold Dock
 - Bulk Cargo Dock
 - Length: 190'
 - Draft: 22.5'
- Small Boat Harbor
 - Floating Dock
 - Length: 120'
 - Draft: 8'



Marine Exchange of Alaska
www.mxak.org

What is the status of existing shore-side support infrastructure? (What is available?)

■ Port of Kotzebue

- Bulk materials wharf
- Privately owned/ operated
- Liquid Cargo Storage: 146,000 Barrels
- Vessel haul-out area: 1.5 acres
- 1.6 acres of unpaved storage
- Berthing Length: ~400'; Draft: 10'

(www.worldportsource.com)

■ Port of Bethel

- Barge dock
- Several miles up Kuskokwim R.



Photo by the Claypool family

What is the status of existing shore-side support infrastructure? (What is available?)

■ Point Hope

- No dock facilities



Photo by Community and Natural Resources Lab, University of Illinois at Urbana-Champaign

■ Unalakleet

- No Dock Facilities



Photo by the Native Village of Unalakleet IRA Council;
<http://www.kawerak.org/tribalHomePages/unalakleet/index.html>

**What is the status of existing
shore-side support infrastructure?**
(What is available?)

- **Red Dog Zinc Mine**
 - ~90 Miles north of Kotzebue
 - East of Kivalina
 - Specialized pier
 - Ore loading



Alaska Department of Commerce, Community, and
Economic Development;
<http://www.commerce.state.ak.us/>

What is the status of existing shore-side support infrastructure? (What is available?)

- “Ports” – North Slope
 - Point Barrow
 - No dock facilities
 - Prudhoe Bay
 - No port



Marine Exchange of Alaska
www.mxak.org

Prudhoe Bay
Photo by Douglas Yates;
“Artists of The Arctic”,
<http://www.arcticrefugeart.org/>

**What is the status of existing
shore-side support infrastructure?**
(What is available?)

- **Other Shore-side Infrastructure**
 - Lodging
 - Food
 - Water/ Wastewater facilities

What is the status of existing shore-side support infrastructure? **(What is available?)**

■ **Other Shore-side Infrastructure**

- Numerous communities along the coast
- However, few options for basing or staging assets – communities would be overwhelmed
- Apparent after USCG, District 17 Forward Operating Location Exercise in 2008, Barrow, AK:

“The existing infrastructure in the U.S. Arctic is insufficient to support prolonged or seasonal Coast Guard operations.”

“Non-governmental berthing/messing in the U.S. Arctic is insufficient to support prolonged or seasonal Coast Guard operations”

What is the status of existing shore-side support infrastructure? (What is available?)

■ Aircraft Facilities



What is the status of existing shore-side support infrastructure? (What is available?)

- In Summary – marine civil infrastructure
 - Locations with “port” facilities:
 - Nome
 - Kotzebue – limited draft
 - Bethel – municipal barge dock
 - Red Dog Mine – specialized (private)
 - Arctic/ Sub-arctic coastlines of Alaska lack shore-side civil infrastructure needed to support escalating maritime operations
 - Will likely need facilities to support future operations – both governmental and civilian



**What are the engineering challenges
of building new marine civil
infrastructure to support operations?**

- Challenges to Planning, Designing, Constructing and Maintaining new marine civil infrastructure
 - Challenges of the arctic environment:
 - Extreme cold temperatures
 - Sea-ice
 - Permafrost – terrestrial and sub-sea
 - Accelerating Littoral Drift (from erosion) – due to diminishing sea-ice

**What are the engineering challenges
of building new marine civil
infrastructure to support operations?**

- Challenges to Planning, Designing, Constructing and Maintaining new marine civil infrastructure
 - Challenges in the U.S. Arctic:
 - Bathymetry not well defined
 - Logistical challenges
 - Environmental parameters needed for engineering design are not readily available
 - Need engineering design criteria for the U.S. Arctic

**What are the engineering challenges
of building new marine civil
infrastructure to support operations?**

- **Scenario – Building a port in the Arctic**
- **Engineering Challenges:**
 - Most of the Chukchi and Beaufort seas are shallow near shore
 - Dredge a navigation channel
 - Will accelerated erosion quickly fill in the channel?
 - If we expose sub-sea permafrost, will the soil melt and the channel collapse?
 - Ice-floes are known to gouge the seafloor near shore.
 - Will ice gouging “bulldoze” soil into the channel?
- **Should we explore alternatives to conventional port design?**

**What are the engineering challenges
of building new marine civil
infrastructure to support operations?**

- Scenario – Design an offshore vessel mooring to support operations
- Consult the “Handbook”:
 - UFC 4-159-03 - Design: Moorings
 - Environmental parameters:
 - Consider the possibility of ice
 - If ice is a concern, requires special analysis
 - No further information given

**What are the engineering challenges
of building new marine civil
infrastructure to support operations?**

- Scenario – Design an offshore vessel mooring to support operations
- Engineering Challenges:
 - How do we design a mooring to survive sea-ice?
 - What are the design wind and sea conditions?
 - Data collected to date may not be appropriate for engineering design...why?
 - A reliably engineered system is not designed for the mean, it must be designed for the extreme.
 - What are extreme metocean conditions in the U.S. Arctic?
 - What will they be in the future??...(climate change)

**What are the engineering challenges
of building new marine civil
infrastructure to support operations?**

- Scenario – Design an offshore vessel mooring to support operations
- ISO 19906: Petroleum and natural gas industries – Arctic Offshore structures
 - Design normative intended to answer some of these questions
 - Provides a rational basis for the design of “reliable” offshore structures in the Arctic.
 - However, design values for U.S waters are lacking

What are the engineering challenges of building new marine civil infrastructure to support operations?

- Scenario – Design an offshore vessel mooring to support operations

Table B.8-1 – Chukchi Sea meteorological conditions

	Parameter	Southwest Region		Northwest Region		Southeastern Region		Northeast Region	
		Average Annual Value	Range of Annual Values	Average Annual Value	Range of Annual Values	Average Annual Value	Range of Annual Values	Average Annual Value	Range of Annual Values
Air temperature	Maximum (°C)	27.5	20 to 30	18.2	15 to 20	20	15 to 25	16	10 to 20
	Minimum (°C)	-46	-40 to -50	-46	-40 to -48	-40	-35 to -45	-44	-40 to -50
	Freezing degree days	ND	ND	ND	ND	3300	2500 to 3600	4000	3500 to 4500
Wind speed @ 10 m elevation	10 minute average (m/s)	39	ND	43	ND	ND	ND	ND	ND
Wind direction	Dominant winter (direction / % occurrence)	NE / 33	ND	NE / 33	ND	E / 25 to 35	ND	SE / 25 to 30	ND
	Dominant Summer (Direction / % Occurrence)	E / 29	ND	E / 29	ND	W to NW / 25 to 30	ND	E / 25 to 40	ND
Precipitation	Annual rainfall (mm)	360	ND	265	ND	221	150 to 300	157	100 to 200
	Annual snowfall (mm)	ND	ND	ND	ND	1143	900 to 1400	530	300 to 700
Visibility (fog, snow, etc.)	Annual number days with visibility < 1 km	66	ND	75	ND	> 30	20 to 40	> 30	20 to 40

What are the engineering challenges of building new marine civil infrastructure to support operations?

- Scenario – Design an offshore vessel mooring to support operations

Table B.8-2 – Chukchi Sea oceanographic conditions

	Parameter	Southwest Region		Northwest Region		Southeastern Region		Northeast Region	
		Average Annual Value	Range of Annual Values	Average Annual Value	Range of Annual Values	Average Annual Value	Range of Annual Values	Average Annual Value	Range of Annual Values
Waves - nearshore (< 100 m water depth)	Significant wave height (m)	6.0 to 8.0	12.0 to 14.0	ND	ND	8	6 to 10	6	5 to 8
	Range of zero-crossing periods (sec)	6 to 7	6 to 10	ND	ND	8 to 12	8 to 14	8 to 10	8 to 12
Current	Near surface maximum speed (cm/sec)	0.15 to 0.2	ND	ND	ND	>0.5	-1.0 (localized regions only)	>0.5	-1.0 (localized regions only)
	Bottom maximum speed (cm/sec)	ND	ND	ND	ND	<10	8 to 10	<10	8 to 10
Tidal current	Maximum surface speed (cm/sec)	ND	ND	ND	ND	0.15	0.1 to 0.2	0.15	0.1 to 0.2
Tide	Tidal range (total) (m)	0.3 to 0.6	ND	ND	ND	ND	ND	0.4	0.3 to 0.5
Wind induced surge	Water depth range total (m)	3.0 to 3.7	ND	ND	ND	30 to 32	29 to 33	30 to 32	29 to 33
Water temperature	Average surface salinity (ppt)	28 to 31	ND	ND	ND	8	6 to 10	6	5 to 8
	Summer surface maximum (°C)	6 to 7	ND	ND	ND	16	14 to 18	11	10 to 12
	Summer surface average (°C)	1 to 5	ND	ND	ND	10	8 to 12	8	5 to 7
Seabed geotechnical - ice induced gauge	Gauge depth (m)	ND	ND	ND	ND	ND	ND	ND	ND
Sismic	Water depth range (m)	ND	ND	ND	ND	ND	ND	ND	ND
	Magnitude	ND	ND	ND	ND	ND	ND	ND	ND

Table B.8-3 – Chukchi Sea sea-ice conditions

	Parameter	Southwest Region		Northwest Region		Southeastern Region		Northeast Region	
		Average Annual Value	Range of Annual Values	Average Annual Value	Range of Annual Values	Average Annual Value	Range of Annual Values	Average Annual Value	Range of Annual Values
Occurrence	First ice	Mid Nov	Early Nov – Late Nov	Early Oct	All year	December	Late November to late December	November	Late October to early December
	Last ice	Late June	Early June – late July	Early Aug	All year	May	Late April to late May	July	Mid June to late August
Level ice (first-year)	Landfast ice thickness (m)	1.6 to 1.8	1.5 to 2.0	None	None	1.2	0.9 to 1.2	1.5	1.3 to 1.7
	Floe thickness (m)	0.7 to 1.2	0.1 to 1.8	1.2 to 1.8	0.5 to 2.0	0.5 to 1.2	0.5 to 1.8	0.7 to 1.4	0.7 to 1.8
Rafted ice	Rafted ice thickness (m)	ND	ND	ND	ND	1.0 to 2.0	1.0 to 3.0	1.0 to 2.0	1.0 to 3.0
Rubble fields	Sea height (m)	ND	ND	ND	ND	1 to 2	1 to 3	2	1 to 3
	Length (m)	ND	ND	ND	ND	300 to 1000	300 to 1000	300 to 1000	300 to 1000
Ridges (first-year)	Sea height (m)	1.7 to 2.0	1.5 to 2.5	2.0 to 2.2	1.0 to 2.5	1 to 2	1 to 3	2	1 to 3
	Keel depth (m)	ND	ND	ND	ND	10	8 to 15	10	8 to 15

What are the engineering challenges of building new marine civil infrastructure to support operations?

- Scenario – Design an offshore vessel mooring to support operations

Table B.7-1 – Beaufort Sea meteorological conditions

	Parameter	Average annual value	Range in annual values
Air temperature	Maximum (°C)	20	10 to 30
	Minimum (°C)	-30	-20 to -40
	Freezing degree days	4 500	3 500 to 5 500
Wind speed @ 10 m elevation	10 minute average (m/s)	16 to 22	13 to 33
Wind direction	Dominant winter direction	275°	ND
	Dominant summer direction	50° (50% of strong winds are from N and NW)	ND
Precipitation	Annual rainfall (mm)	150	100 to 200
	Annual snowfall (mm)	750	600 to 1 100
Visibility (fog, snow, etc.)	Annual number of days with visibility less than 5 miles	20 % of the time	ND

Table B.7-2 – Beaufort Sea oceanographic conditions

	Parameter	Average annual value	Range in annual values
Waves – offshore (> 100m water depth)	Significant wave height (m)	2.3	0.5 to 3.8
	Range of zero-crossing periods (sec)	7.3	3.7 to 9.2
Current	Near surface maximum speed (cm/sec)	4	2 to 6
	Bottom maximum speed (cm/sec)	ND	ND
Tidal current	Maximum surface speed (cm/sec)	ND	ND
Tide	Tidal range (total) (m)	ND	ND
Wind induced surge	Water depth increase range total (m)	ND	ND
	Average surface salinity (ppt)	2 to 30	ND
Water temperature	Summer surface maximum (°C)	ND	ND
	Summer surface average (°C)	Up to 10 C	ND
Seabed geotechnical –	Gouge depth (m)	4.5	6 to 7

**What are the engineering challenges
of building new marine civil
infrastructure to support operations?**

- Engineering design criteria for the U.S Arctic
 - *"A problem fully defined is a problem partially solved..."*
 - Environmental demands on new Arctic marine civil infrastructure must be well-understood to design successful engineered systems

**What are the engineering challenges
of building new marine civil
infrastructure to support operations?**

- **Engineering design criteria for the U.S Arctic**
 - Environmental demands on marine transportation infrastructure (**E.g., harbors, port facilities, offshore moorings**) in the Arctic:
 - Design wind speed
 - Design wave height
 - Design current velocity
 - **Understand sub-sea permafrost**
 - Sea-ice
 - Thickness distribution in the various regions
 - Mechanical properties (e.g., strength of sea ice)
 - Design floe velocity

What are the engineering challenges
of building new marine civil
infrastructure to support operations?

- Engineering design criteria for the U.S Arctic
 - Must characterize the **extreme-value events** – statistically low probability of occurrence
 - This information is necessary to design and construct **safe** and **reliable** infrastructure
 - **Safe** for those that use the facility, or may be impacted by a failure
 - **Reliable** so the facilities are functional when needed

What are the engineering challenges
of building new marine civil
infrastructure to support operations?

- Engineering design criteria for the U.S Arctic
 - “Reliability-based” engineering practices exist –
E.g., buildings, highway bridges, water,
wastewater systems, etc.
 - Require input appropriate for the U.S. Arctic
 - Need the **mean + dispersion** of data to
identify extreme values

**What are the engineering challenges
of building new marine civil
infrastructure to support operations?**

- Engineering design criteria for the U.S Arctic
 - My view:
Developing reliability-based engineering design criteria for “our” Arctic will require a strong collaborative relationship between scientists and engineers that specialize in cold regions issues.

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